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First discovery of a magnetic field in a main sequence δ Scuti star: the *Kepler* star HD 188774*

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ABSTRACT
The *Kepler* space mission provided a wealth of δ Sct-γ Dor hybrid candidates. While some may be genuine hybrids, others might be misclassified due to the presence of a binary companion or to rotational modulation caused by magnetism and related surface inhomogeneities. In particular, the *Kepler* δ Sct-γ Dor hybrid candidate HD 188774 shows a few low frequencies in its light and radial velocity curves, whose origin is unclear. In this work, we check for the presence of a magnetic field in HD 188774. We obtained two spectropolarimetric measurements with ESPaDOnS at CFHT. The data were analysed with the least squares deconvolution method. We detected a clear magnetic signature in the Stokes V LSD profiles. The origin of the low frequencies detected in HD 188774 is therefore most probably the rotational modulation of surface spots possibly related to the presence of a magnetic field. Consequently, HD 188774 is not a genuine hybrid δ Sct-γ Dor star, but the first known magnetic main sequence δ Sct star. This makes it a prime target for future asteroseismic and spot modelling. This result casts new light on the interpretation of the *Kepler* results for other δ Sct-γ Dor hybrid candidates.

Key words: stars: magnetic fields – stars: oscillations – stars: variables: δ Scuti – stars: starspots – stars: individual: HD 188774

1 INTRODUCTION

The region of the Hertzsprung-Russell (H-R) diagram where A and F stars are located shows a rich variety of stellar atmospheric processes, several of which can produce short- and/or long-term variability. These processes consist in different pulsation mechanisms, as well as various other phenomena involving convection, diffusion, rotation, and even magnetic fields. Multiplicity, which has a non-negligible impact on some processes, is an additional cause for variability. As an illustration, the binary fraction of a sample of A-F stars from the Sco-Cen association is found to lie between 60 and 80% (Janson et al. 2013).

The A and F stars define some of the most populated groups of pulsators: namely the δ Scuti (δ Sct) and γ Doradus (γ Dor) stars. They have masses between 2.5 and 1.5 $M_\odot$. The δ Sct and γ Dor stars are found in neighbouring, even overlapping, regions of the H-R diagram. The driving mechanism of the δ Sct stars is the κ mechanism operating in the He II ionisation region (Pamyatnykh 2000), producing p modes. The driving mechanism of the γ Dor pulsators is convective blocking near the base of their convective envelopes (Guzik et al. 2000; Dupret et al. 2004), producing g modes. This mechanism can only operate if the outer convective layer has a depth between 3 and 9% of the stellar radius. The overlapping region, where both types of pulsation modes can co-exist, yields the potential to constrain physical properties in the various internal layers of the star, from the core to the outer envelope. The hybrid pulsators are thus very promising targets for asteroseismic studies.

Before the advent of asteroseismic space missions, only a few stars were known to show characteristics of both pulsation types. The first hybrid γ Dor-δ Sct star was discovered from the ground (Henry & Fekel 2005). Meanwhile, hundreds of candidate hybrid pulsators have been identified by asteroseismic space missions. The first results based on data collected by the *Kepler* mission (Grigahcène et al. 2010; Uytterhoeven et al. 2011) suggest that the number of hybrid candidates is much higher than expected. However, the fact that many are found across the full width of both

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observational instability strips poses a serious problem. If the majority of the candidates were proven to be true hybrids, current theory would need to be revised (e.g. confrontation of Figs. 2 and 3 in Grigahcène et al. 2010). The origin of the low frequencies (< 5 c d^{-1}) found in the periodograms of practically all of the *Kepler* δ Sct stars (Balona 2014; Balona et al. 2015), often attributed to hybrid pulsation, is thus puzzling, in particular for the hottest ones. Therefore, it is very important to assess whether the hybrid candidates are all genuine hybrid pulsators.

Presently, about a dozen of genuine hybrids have been confirmed by detailed investigations (e.g. Hareter 2012; Tkachenko et al. 2013), while the classification of many new candidates rests on a "first-look" photometric analysis. A careful study of 69 candidate γ Dor stars with spectroscopically determined atmospheric parameters, of which 14 were identified as γ Dor-δ Sct hybrids, rather suggests that genuine hybrids are confined to the effective temperature interval [6900:7400] K, as theory predicts (see Fig. 15 in Dupret et al. 2005).

Two other plausible scenarios can be considered to explain the presence of low frequencies in δ Sct stars, without invoking γ Dor pulsations:

First, pulsations can be superposed to the light curve of a binary star. In this case, the object is an eclipsing or an ellipsoidal system (low frequencies) with a δ Sct component (high frequencies). Additionally, if the binary forms a close system, pulsations may be affected by distorted stellar shapes and tidal interactions (Reyniers & Smeyers 2003a,b). If the eccentricity becomes significant, tidally excited g-modes may arise (e.g. Hambleton et al. 2013). Another possibility consists in a binary with two components pulsating in different frequency modes (i.e. a δ Sct star with a γ Dor companion).

Second, the object can be a δ Sct star with some surface inhomogeneity. In this case, the presence of large temperature gradients or abundance variations (spots) on the stellar surface in combination with stellar rotation induces low frequencies of the order of the rotational period (and its harmonics) in the light curves (Balona 2011, 2013).

In this Letter, we discuss and evaluate the various scenarios for the *Kepler* δ Sct-γ Dor candidate HD 188774 (Sect. 2). In particular, we address the scenario of rotational modulation (Sect. 3). We then present the spectropolarimetric results (Sect. 4) and draw conclusions (Sect. 5).

2 HD 188774

The *Kepler* δ Sct-γ Dor (A7.5IV-III) hybrid candidate HD 188774 (KIC 5988140) was selected for a thorough study by Lampens et al. (2013b) (see also Lampens et al. 2013a), who also acquired 40 high-resolution spectra with ground-based instruments. Fourier analysis of these data revealed nine significant frequencies of the order of several hours, thus confirming the δ Sct oscillations. Furthermore, Fourier analysis of both light and radial velocity (RV) curves revealed two additional low frequencies of higher amplitude (f_1=0.68799 and f_2=0.343984 d^{-1}).

At first sight, the *Kepler* light curve of HD 188774 mimics an eclipsing binary system with superposed short-period variations of δ Sct type. Although there is a strict 1:2 ratio between the dominant low frequencies corresponding to the possible effects of ellipsoidality and reflection in the light curve, Lampens et al. (2013b) ruled out the explanation of orbital motion because the RV curve almost perfectly matches the variability pattern of the mean light curve (after prewhitening of all the high frequencies).

In addition, with respect to the scenario of genuine hybrid pulsation, we find several counter-arguments. Firstly, the exact integer ratio 1:2 between the two most dominant low frequencies, the detection of additional harmonics of the lowest frequency, and the phase relation between the two curves are atypical for non-radial g-mode pulsations. Moreover, Lampens et al. (2013b) noted that the light-to-velocity amplitude ratio is also very unusual: the observed amplitude ratio is of the order of 0.63 mmag/km s^{-1}, whereas e.g. Aerts et al. (2004) derived a mean ratio of about 15 mmag/km s^{-1} from an asteroseismic study of two bright γ Dor stars. In addition, the effective temperature of HD 188774 (7600 $\pm$ 30 K, Lampens et al. 2013b) is outside the temperature interval for genuine hybrid stars.

Since both binarity and g-mode pulsations seem very unlikely, we investigated below the third scenario, i.e. rotational modulation, as an explanation for the low frequencies of variations observed in HD 188774.

3 ROTATIONAL MODULATION IN HD 188774

Although A-type stars usually have homogeneous stellar surfaces due to their large radiative envelopes with only shallow subsurface convection, a few do present observable inhomogeneous surface distributions. There are two possible reasons:

(1) This can be due to (very) rapid rotation inducing large temperature gradients (e.g. Altair; Peterson et al. 2006). In the case of HD 188774, one finds that critical rotation is highly improbable. Indeed, adopting the radius listed in the *Kepler* Input Catalog (KIC) and assuming that $P_2 =$ 2.90711 d from Lampens et al. (2013b) is the rotation period, one finds that $V_{\rm eq} = 62.3$ km s^{-1}. A comparison with the measured $v \sin i$ gives a probable inclination angle of $i \sim 50°$. In addition, Lampens et al. (2013b) found no temperature variations between spectra taken at four different rotational phases.

(2) Another possible cause is local chemical inhomogeneities called "spots" (e.g. Lehmann et al. 2006; Lüftinger et al. 2010; Kochukhov 2011). For HD 188774, Lampens et al. (2013b) used two simple models with symmetrically located spots to represent as closely as possible the behaviour of the RV curve (cf. their Fig. 10). Both models predict a peak-to-peak light amplitude of the order of 20%, while the total amplitude of the *Kepler* light curve is only 0.5% (i.e. 5 ppt). Because of this qualitative disagreement, they discarded the model of a spotted surface for HD 188774 as the explanation for the observed variations. However, more sophisticated spot models, which might explain the observed variations, were not tested.

A major issue with the scenario of chemical spots is to be able to identify a possible physical cause to explain their presence. Single A stars, in general, do not have chemically spotted surfaces, unless they possess a magnetic field. This is the case for most CP stars. In particular, Ap stars host

Table 1. Spectropolarimetric measurements of HD 188774. The dates, heliocentric Julian dates corresponding to the middle epoch of the measurements, and exposure times are given. The computed longitudinal field B_l and N values, with their respective error bars σ and significance level z are also shown, as well as the field detection probability in % and in terms of type of detection.

Date	Mid-HJD -2450000	$T_{\rm exp}$ s	$B_l \pm \sigma_B$ G	z_B	$N \pm \sigma_N$ G	z_N	Prob. %	Detect.
Sep 7, 2014	2456907.951	4×840	23.2 ± 17.1	1.4	6.9 ± 17.1	0.4	99.999%	Definite
Jul 23, 2015	2457227.027	10×4×129	75.8 ± 13.0	5.8	7.6 ± 12.9	0.6	100%	Definite

very strong magnetic fields (e.g. Mathys 2001), which break stellar rotation and stabilize the atmosphere, enabling processes of atomic diffusion (e.g. Alecian 2013). Most of the He-strong and He-weak stars are also known to host magnetic fields, and their He peculiarity is interpreted both in terms of elemental diffusion and of the fractionation of their stellar magnetized wind (Hunger & Groote 1999). In addition, recent results show that Am stars can possess ultra-weak fields (Petit et al. 2011; Blazère et al. 2014). While their low rotational velocity is usually attributed to their binary nature, their magnetic fields may also contribute to enabling the diffusion process. On the other hand, no HgMn stars have been found to host a magnetic field so far, in spite of their chemical peculiarity (e.g. Makaganiuk et al. 2011). Finally, there seems to be no known A star with a fossil magnetic field of average strength: either the fields are strong (B_l >100 G), e.g. in Ap stars, or they are ultra weak (B_l < 1 G), e.g. in Am stars. This phenomenon is referred to as the magnetic dichotomy in intermediate-mass stars (Aurière et al. 2007; Lignières et al. 2014).

The abundance analysis of HD 188774 did not show any chemical peculiarity, nor abundance variations across the stellar surface (Lampens et al. 2013b). It is nevertheless possible that this δ Sct star hosts a fossil magnetic field, as seen in 10% of hot stars (Grunhut & Neiner 2015). The field could be too weak to produce chemical peculiarities or the pulsations could dominate the field in terms of internal mixing. Moreover, Lampens et al. (2013b) demonstrated an extremely stable *Kepler* light curve over a period of (at least) T = 682 days, indicating that, if spots are present on the surface of HD 188774, they should remain stable over a few years. A fossil magnetic field could explain such long-term spot stability.

A direct detection of a magnetic field has already been obtained in at least one non-peculiar A star: Vega (Lignières et al. 2009; Petit et al. 2010). This star is a very rapid rotator seen pole-on and hosts an ultra-weak field (B_l = 0.6 G) located in a spot near the rotation pole. In addition, Böhm et al. (2012, 2015) reported very small amplitude stellar radial velocity variations, associated to either pulsations or rotational modulation. Thus, they showed that non-peculiar A-type stars can have structures observable at the surface.

In addition, other indirect evidence for magnetism has been detected in some A stars, in particular in X-rays (Schröder & Schmitt 2007). This activity may be related to a dynamo field, similar to cooler stars. However, no direct detection of a magnetic field has ever been obtained in these active A stars.

Finally, magnetic A stars can undergo pulsations. In particular, very fast oscillations occur in some Ap stars (the roAp stars, see Mathys et al. 1997; Kochukhov 2008). However, no δ Sct pulsations have been detected in a magnetic star so far, in spite of some attempts: Kurtz et al. (2008) claimed the first observational evidence for δ Sct pulsations and magnetic field in an Ap star (HD 21190; see also Balona et al. 2011). However, Bagnulo et al. (2012) showed that this magnetic detection was spurious and that the star is probably not an Ap star. Conversely, Alecian et al. (2013) claimed a possible magnetic detection in the δ Sct star HD 35929. However, their 5 spectropolarimetric measurements gave contrasting results and this star is a pre-main sequence Herbig Ae star.

4 SPECTROPOLARIMETRIC OBSERVATIONS

We obtained two circular spectropolarimetric measurements of HD 188774 with ESPaDOnS at CFHT. The first one was obtained on September 7, 2014 to test the hypothesis of the presence of a magnetic field in this star. This measurement consists of 4 subexposures obtained in different configurations of the polarimeter. The exposure time was 4×840 s, i.e. 3360 s in total. The signal-to-noise ratio (S/N) in the intensity spectrum I peaks at 587. Using the published RV ephemeris, our measurement corresponds to phase 0.189, close to the minimum value of the RV curve (see Fig. 3 in Lampens et al. 2013b). To confirm the detection of a Zeeman signature in this first spectropolarimetric measurement, a second measurement was acquired on July 23, 2015, which corresponds to phase 0.950, close to the maximum value of the RV curve. This measurement was obtained with 10 successive sequences of 4×129 s each, i.e. 5160 s in total, to make sure that the Zeeman signature is not polluted by the short-scale pulsations. See Table 1.

The spectra were reduced with the Libre-Esprit (Donati et al. 1997) and Upena pipelines at CFHT. We obtained the intensity I spectra, Stokes V spectra, as well as null N polarisation spectra to check for spurious signatures. We normalised the spectra to the continuum level with IRAF.

Next, we applied the least squares deconvolution (LSD) method (Donati et al. 1997). This state-of-the-art technique is the most suited to extract weak magnetic signatures in stellar spectra, as it allows to increase the S/N of the magnetic signature by combining all available lines and weakens at the same time signatures that would be present only in a few lines (thus probably not of magnetic origin). The lines are combined using weights proportional to the line strength, wavelength λ, and Landé factor g.

The line mask used in these LSD calculations was extracted from the VALD database (Piskunov et al. 1995;

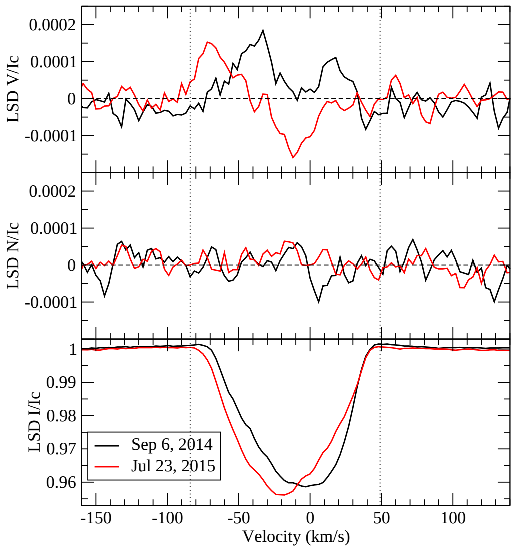

Figure 1. Stokes V (top), N (middle), Stokes I (bottom) LSD profiles of HD 188774 for the first (black) and second (red) measurements. Vertical dotted lines indicate the width of the profile over which the FAP and longitudinal field were calculated.

Kupka et al. 1999). We adopted the atmospheric parameters $T_{\rm eff}$=7600 K and $\log g$=3.39 (Lampens et al. 2013b), assumed solar abundances, and extracted only lines with a depth of 1% or more of the continuum level for the initial mask. From this line mask, we then rejected all hydrogen lines, as well as lines blended with the H lines and/or contaminated by telluric lines. The final mask contains 5260 lines, with an average Landé factor of 1.191-1.192 and an average wavelength of 522.88-520.36 nm for the two measurements, respectively. We then automatically adjusted the line depths to provide the best fit to the observed Stokes I spectra.

For the second measurement, we co-added the 10 LSD profiles. The I, V and N LSD profiles of both measurements are shown in Fig. 1. The S/N of the Stokes I and V LSD profiles is 1950 and 15240 for the first measurement and 7520 and 19300 for the second measurement, respectively.

The N profile is a combination of the spectropolarimetric subexposures in such a way that the Zeeman signature of the stellar magnetic field cancels out (Donati et al. 1997; Bagnulo et al. 2009). Only non-magnetic effects remain in the N profile. The flat N LSD profiles (Fig. 1) show that the measurements have not been contaminated by external sources, such as an instrumental problem, although the first profile presents a small deviation from the mean around 0 km s^{-1}. Since this measurement was obtained with longer subexposures, corresponding to 1 to 23% of the pulsation periods, it is possible that pulsations have slightly influenced the profiles. In contrast, the Stokes V LSD profiles show clear Zeeman signatures.

We computed the False Alarm Probability (FAP) of a detection in the LSD Stokes V profiles inside the velocity range of the line ([-84:49] km s^{-1}), compared to the mean noise level outside the line. We used the convention defined by Donati et al. (1997): if FAP $<$ 0.001%, the magnetic detection is definite, if 0.001% $<$ FAP $<$ 0.1% the detection is marginal, otherwise there is no magnetic detection. Both measurements represent definite detections of a magnetic field. On the contrary, no detection is found, neither outside the line, nor in the N profiles. Therefore, we can discard effects due to instrumental origins or noise.

The two measurements show different shapes of the magnetic signatures. As expected for a dipolar field, the first measurement obtained close to minimum RV phase shows a symmetrical crossover signature, while the second measurement taken close to maximum RV shows an asymmetrical signature (i.e. we see the magnetic pole).

The shape of the magnetic signature in the first measurement may be reminiscent of signatures observed in Am stars (e.g. Blazère et al. 2014). In these stars, the positive double-lobe shape of the magnetic signatures is tentatively explained by shocks in the thin convective layer (Blazère et al. 2015). However, it is more likely that this signature was obtained during a magnetic crossover phase and that the central part of the signature does not reach negative values because the profile is slightly modified by pulsations due to the long subexposure time (as suggested by the N profile).

Next, we computed the longitudinal field strength B_l from the Stokes I and V LSD profiles (following Rees & Semel 1979; Wade et al. 2000), using the velocity range between -84 and 49 km s^{-1}. A similar calculation was performed using the N profile instead of V. The values of B_l, N, their error bars, and significance level are indicated in Table 1. As expected the first crossover measurement corresponds to a B_l close to 0, while the second measurement is higher (~76 G). The higher significance level in B_l than in N (see Table 1) confirms that the magnetic signature has a stellar origin.

5 CONCLUSIONS

The ESPaDOnS spectropolarimetric measurements of the *Kepler* hybrid candidate HD 188774 exhibit definite magnetic signatures. Our result is the very first detection of a magnetic field in a main sequence δ Sct pulsating star and refutes the hybrid character of HD 188774.

The possible existence of a dynamo magnetic field is unlikely, since most normal A-type stars are found to be inactive: they are generally X-ray poor (~85% of the sample observed by Schröder & Schmitt 2007) and only very exceptionally do they also show flares in their light curves (Balona 2012). On the contrary, fossil magnetic fields are found in ~10% of hot stars (Grunhut & Neiner 2015). Most of these magnetic A stars are the well-known Ap stars, but a small fraction of them could be normal A stars, and a small fraction of those could host δ Sct pulsations. HD 188774 is the first such example to be discovered.

The observed relatively simple Zeeman signatures indeed point to a possible fossil origin of the field (as for OB and Ap stars), rather than to a dynamo. This is also consistent with the long-term stability of the proposed spots at the surface of HD 188774, verified in the *Kepler* light curve. In addition, our measurements of the longitudinal magnetic field of HD 188774 are below 100 G, which appears to lie on the edge of the dichotomy desert between strong and ultra-weak fossil fields, as defined by Aurière et al. (2007). However, such values suggest a polar field strength of a few

hundred gauss, which is typical of fossil fields in non-peculiar OB stars.

Although Lampens et al. (2013b) considered the presence of spots as unlikely, especially because of the small light-to-velocity amplitude ratio, the detection of a magnetic field in HD 188774 now makes this explanation to the observed low frequencies of variations most plausible. Further spectropolarimetric observations of this star covering a full rotation period should allow us to constrain the magnetic field configuration and polar field strength.

In addition, the analysis of the pulsational properties of HD 188774 based on the *Kepler* light curve revealed nine significant δ Sct-type frequencies (Lampens et al. 2013b). Since we now know that the star possesses a magnetic field, HD 188774 is a very promising target for a detailed seismic and spotted surface modelling, as well as for a study of the impact of the magnetic field on its internal structure, mixing, convection, and oscillations.

HD 188774 might well be the first member of a new class of weakly magnetic δ Sct stars. (Some of) the low frequencies observed in the light curves of more candidate hybrid δ Sct-γ Dor stars might be due to rotational modulation induced by spots on their stellar surface, i.e. that they might also turn out to be magnetic δ Sct stars rather than hybrid stars. This casts new light on the analysis and interpretation of the *Kepler* results for the diversified and intriguing class of A-type stars.

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REFERENCES

Aerts C., Cuypers J., et al. 2004, A&A, 415, 1079
Alecian E., Wade G., et al. 2013, MNRAS, 429, 1001
Alecian G., 2013, in Shibahashi H., Lynas-Gray A. E., eds, Progress in physics of the sun and stars Vol. 479 of ASPCS. p. 35
Aurière M., Wade G. A., et al. 2007, A&A, 475, 1053
Bagnulo S., Landolfi M., et al. 2009, PASP, 121, 993
Bagnulo S., Landstreet J. D., Fossati L., Kochukhov O., 2012, A&A, 538, A129
Balona L. A., 2011, MNRAS, 415, 1691
Balona L. A., 2012, MNRAS, 423, 3420
Balona L. A., 2013, in Shibahashi H., Lynas-Gray A. E., eds, Progress in physics of the sun and stars Vol. 479 of ASPCS. p. 385
Balona L. A., 2014, MNRAS, 437, 1476
Balona L. A., Cuhna M., et al. 2011, MNRAS, 410, 517
Balona L. A., Daszyńska-Daszkiewicz J., Pamyatnykh A. A., 2015, MNRAS, 452, 3073
Blazère A., Neiner C., et al. 2015, A&A in press
Blazère A., Petit P., et al. 2014, in Ballet J., Martins F., Bournaud F., Monier R., Reylé C., eds, SF2A-2014 p. 463
Böhm T., Holschneider M., et al. 2015, A&A, 577, A64
Böhm T., Lignières F., et al. 2012, A&A, 537, A90
Donati J.-F., Semel M., Carter B. D., Rees D. E., Collier Cameron A., 1997, MNRAS, 291, 658
Dupret M.-A., Grigahcène A., Garrido R., Gabriel M., Noels A., 2004, in Danesy D., ed., SOHO 14 Helio- and Asteroseismology: Towards a Golden Future Vol. 559 of ESA SP. p. 207
Dupret M.-A., Grigahcène A., Garrido R., Gabriel M., Scuflaire R., 2005, A&A, 435, 927
Grigahcène A., Antoci V., et al. 2010, ApJ, 713, L192
Grunhut J. H., Neiner C., 2015, in Nagendra K., Bagnulo S., Centeno R., Martínez González M., eds, Polarimetry: from the Sun to stars and stellar environments Vol. 305 of IAU Symposium. p. 53
Guzik J. A., Kaye A. B., Bradley P. A., Cox A. N., Neuforge C., 2000, ApJ, 542, L57
Hambleton K. M., Kurtz D. W., et al. 2013, MNRAS, 434, 925
Hareter M., 2012, AN, 333, 1048
Henry G. W., Fekel F. C., 2005, AJ, 129, 2026
Hunger K., Groote D., 1999, A&A, 351, 554
Janson M., Lafrenière D., et al. 2013, ApJ, 773, 170
Kochukhov O., 2008, CoAst, 157, 228
Kochukhov O., 2011, in Prasad Choudhary D., Strassmeier K. G., eds, Physics of Sun and star spots Vol. 273 of IAU Symposium. p. 249
Kupka F., Piskunov N., Ryabchikova T. A., Stempels H. C., Weiss W. W., 1999, A&AS, 138, 119
Kurtz D. W., Hubrig S., González J. F., van Wyk F., Martinez P., 2008, MNRAS, 386, 1750
Lampens P., Tkachenko A., et al. 2013a, in Shibahashi H., Lynas-Gray A. E., eds, Progress in Physics of the Sun and Stars: A New Era in Helio- and Asteroseismology Vol. 479 of ASPCS. p. 99
Lampens P., Tkachenko A., et al. 2013b, A&A, 549, A104
Lehmann H., Tsymbal V., Mkrtichian D. E., Fraga L., 2006, A&A, 457, 1033
Lignières F., Petit P., Aurière M., Wade G. A., Böhm T., 2014, in Magnetic Fields throughout Stellar Evolution Vol. 302 of IAU Symposium. p. 338
Lignières F., Petit P., Böhm T., Aurière M., 2009, A&A, 500, L41
Lüftinger T., Fröhlich H.-E., et al. 2010, A&A, 509, A43
Makaganiuk V., Kochukhov O., et al. 2011, A&A, 529, A160
Mathys G., 2001, in Mathys G., Solanki S. K., Wickramasinghe D. T., eds, Magnetic Fields Across the Hertzsprung-Russell Diagram Vol. 248 of ASPCS. p. 267
Mathys G., Hubrig S., Landstreet J. D., Lanz T., Manfroid J., 1997, A&AS, 123, 353
Pamyatnykh A. A., 2000, in Breger M., Montgomery M., eds, Delta Scuti and Related Stars Vol. 210 of ASPCS. p. 215
Peterson D. M., Hummel C., et al. 2006, ApJ, 636, 1087
Petit P., Lignières F., et al. 2010, A&A, 523, A41
Petit P., Lignières F., et al. 2011, A&A, 532, L13
Piskunov N. E., Kupka F., Ryabchikova T. A., Weiss W. W., Jeffery C. S., 1995, A&AS, 112, 525
Rees D. E., Semel M. D., 1979, A&A, 74, 1
Reyniers K., Smeyers P., 2003a, A&A, 409, 677
Reyniers K., Smeyers P., 2003b, A&A, 404, 1051

Schröder C., Schmitt J. H. M. M., 2007, A&A, 475, 677
Tkachenko A., Lehmann H., Smalley B., Uytterhoeven K., 2013, MNRAS, 431, 3685
Uytterhoeven K., Moya A., et al. 2011, A&A, 534, A125
Wade G. A., Donati J.-F., Landstreet J. D., Shorlin S. L. S., 2000, MNRAS, 313, 851

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